FISH PASSAGE CENTER

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MEMORANDUM

TO: Tom Lorz (CRITFC), chair of FPOM Task Group on BON Unit Operating Range

FROM: Michele DeHart

DATE: December 17, 2012

RE: Effects of operations at Bonneville Dam second powerhouse and juvenile sample mortalities, 2008-2012.

In July of 2012, the Fish Passage Center was asked by the FPOM Task Group on Bonneville Dam Unit Operating Range to conduct an analysis of operations data from the Bonneville Dam second powerhouse (BON-PH2) and juvenile sample mortality data from the Smolt Monitoring Program (SMP). Specifically, the FPC was asked to investigate whether there was evidence that operating above the mid-range of the 1% efficiency curve at BON-PH2 in 2008 through 2012 resulted in increased levels of sample mortalities. Below is a brief summary of our results, followed by a more detailed explanation of the methods and analyses that were conducted for this request.

- The FPC conducted ANCOVA analyses to determine whether daily operations at BON-PH2 had an effect on daily sample moralities. Independent variables for these analyses included: 1) the percent of operating units that operated above the mid-range and 2) Julian Day.
- Based on these ANCOVA analyses, the percent of units operating above the mid-range often had a significant effect on sample mortalities, particularly for subyearling Chinook, sockeye, and yearling Chinook.
- In general, for subyearling Chinook, sockeye, and yearling Chinook, as the percent of units operating above the mid-range increased, average sample mortality also increased. In fact, sample mortality was often significantly higher when >95% of BON-PH2 units operated above the mid-range than when <5% of BON-PH2 units operated above the mid-range.

Background:

The issue of operating BON-PH2 at the high end of the 1% efficiency range was raised during the 2012 juvenile salmon migration. On April 11, 2012, approximately 925,400 subyearling fall Chinook were released from Spring Creek NFH, which is located about 35 kilometers above BON. An additional 7.03 million subyearling fall Chinook juveniles were released from Spring Creek NFH and Little White Salmon NFH on April 13, 2012. The fish from the April 11th release were first encountered by the SMP crews at BON at about 0040 on April 12th. Subsequent to their arrival sample mortality rates of subyearling Chinook began to increase. The sample ending on April 13th had a daily mortality of 15.2% (which incorporates some mortality due to the cleaning of the screens) for subyearling Chinook.

Due to these high mortalities, and the release of 7.03 million additional subyearling Chinook on April 13th, the salmon managers submitted a System Operational Request (SOR 2012-1) for a special operation at BON during the peak passage of the subyearling Chinook released on April 13th. The SOR requested that all units at BON-PH2 operate at the mid-point of the 1% efficiency range, establishing a lower hydraulic capacity for the project, and spill any additional water above this hydraulic capacity.

The Corps of Engineers (COE) proposed an alternative operation, which called for no additional spill and included the operation of BON-PH1 in open geometry to minimize the time that units at BON-PH2 would operate at the higher end of the 1% efficiency range. This action effectively reduced spill by forcing more water to BON-PH1 and therefore generating more electricity through BON-PH1. The issue with operating the project at open geometry is that there are no “empirical” data to suggest that forcing more fish through BON-PH1 presents the better fish operation. In addition, there is no monitoring at BON-PH1 and, therefore, if there was additional mortality imposed on these fish, there is no way of knowing or measuring the impact. The Action Agencies alternative operation was implemented on the afternoon of April 13th and continued off and on until the majority of the juvenile Snake River sockeye run had passed in mid-June.

During the May 16th TMT discussion, it was determined that a more permanent solution was needed for these types of incidences. It was decided that discussions of a permanent solution should be held in various regional forums, including the Fish Passage Operations Managers (FPOM), Fish Facility Design Review Work Group (FFDRWG), and Scientific Review Work Group (SRWG). An FPOM Task Group was convened in July to addresses these concerns, with the goal of offering a more permanent solution. Discussions of this FPOM Task Group led to this data request.

Methods:

Summary of Operations Data

FPC staff received Bonneville Dam unit operations data from the COE for the juvenile migration period for 2008-2012 (May 1-July 31 for 2008, March 1-July 31 for 2009-2011, and March 1-June 30 in 2012). Unit operations data from BON-PH2 were then summarized into daily averages. The daily average operations were estimated for the 7:00 am to 7:00 am period, as these are the time periods when Smolt Monitoring Program (SMP) mortality data are collected. As with SMP data, the “date” for the daily average unit operation was based on the end-day of the period. Unit operations data were adjusted for periods when individual turbines were off-line. For example, if a turbine was off-line for one hour, then the daily average flow for that turbine was estimated from the 23 hours that it was in operation. Each operating unit was then given a weight, based on how many hours that unit was in operation. For example, a unit that operated for the entire 24-hour period received a weight of 1.0, while a unit that operated for only 12 hours received a weight of 0.5. The sum of these weights was used to determine the total number of units that were in operation for a given day. The maximum value possible for this variable is 8.0.

To determine if the daily operations for each unit were outside the mid-range of the 1% efficiency curve, we relied on Table BON-16 of the 2012 Fish Passage Plan (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2012/index.html). Based on the daily average head for that unit, we determined the upper limit of the mid-range by estimating the mid-point between the lower limit and upper limit of the 1% efficiency curve. If the daily average flow through the unit was above the estimated mid-range flow, that unit was determined to exceed the mid-range of the 1% efficiency curve. For those units that were determined to exceed the mid-range of the 1% efficiency curve, we applied a weighting factor, based on how many hours the unit was in operation. For example, if the daily average flow through an exceeding unit was based on 12-hours of data, the weight of that unit was 0.5, whereas an exceeding unit with 24-hours of data would receive a weight of 1.0. Units that were found to not exceed the mid-range of the 1% efficiency curve received a weight of 0.0. The sum of these weights was used to determine how many total units were exceeding the mid-range of the 1% efficiency curve, with a maximum possible value of 8.0. Finally, we estimated the percent of operating units that exceeded the mid-range of the 1% efficiency curve by dividing the number of units operating above the mid-range of the 1% efficiency curve by the total number of units operating. Here-in, we refer to this variable as percent of the units operating above the mid-point (***PrAboveMid)***.

Upon further investigation of operations data, it was clear that the percentage of units operating above the mid-range was not normally distributed, as most times very few (<5%) units were operated above the mid-point or most all (>95%) units were operated above the mid-point, with very few exceptions. Consequently, ***PrAboveMid*** was converted into a categorical variable by grouping the days into four possible categories: 1) ≤5% operating above mid-range, 2) 5-50% operating above mid-range, 3) 50-95% operating above mid-range, and 4) ≥95% operating above mid-range.

Three other independent variables were considered for these analyses but were not included after further investigation. These three independent variables were: 1) total discharge from the second powerhouse, 2) temperature, and 3) fish length. Total discharge from the second powerhouse had a high degree of correlation with ***PrAboveMid*** (e.g., 0.67 for subyearling Chinook in 2012). Because of this high auto-correlation, only one variable could be included in the analyses: ***PrAboveMid***. In addition, temperature and fish length were both considered for this analysis. However, both of these variables are correlated with ***Julian Day***, as both tend to increase as the year progresses. Therefore, we only included ***Julian Day*** in the analyses. ***Julian Day*** may also reflect changes in operations, as operations are adjusted on a daily, and sometimes seasonal, basis; often in response to high mortality events. Another reason for not including fish length was because lengths were not collected for all species over the entire season. For example, although subyearling Chinook are sampled at BON from April through the end of the SMP season, length data are generally not collected for subyearling Chinook at BON until June. Therefore, we were missing lengths for all subyearling Chinook sampled in April and May, which is often the period of highest mortality for this species. In addition, lengths are not recorded for the mortalities. This means that the only length data that are available are from the survivors, which is likely a bias sample and not representative of the mortalities.

ANCOVA Analyses

We relied on analysis of covariance (ANCOVA) to determine whether daily operations at BON-PH2 had an effect on daily sample moralities from the SMP. ANCOVA is typically used to evaluate whether means of a dependent variable (i.e., sample mortality) are equal across levels of a categorical independent variable (i.e., ***PrAboveMid***) while controlling for the effects of continuous variables or covariates (i.e., ***Julian Day***). Separate ANCOVA analyses were conducted for each species of juvenile salmonid that was sampled by the SMP crew at BON. In order to balance the ability to have enough data to analyze in a single year and to minimize the effect of days with low sample sizes of fish, we limited these analyses to days where the sample count for a given species was ≥50 individuals. Finally, to determine whether there were significant differences in the average sample mortalities between the different levels of ***PrAboveMid,*** we conducted Tukey's tests.

Results:

Table 1. Summary of results from ANCOVA analyses of mortality data and effects of ***PrAboveMid*** and ***Julian Day***. Values in bold-italics indicate significant factor at the $\alpha = 0.05$ level. Full results of ANCOVA analyses are available in Appendix A.

Species	Migration Year	ANCOVA p-value	
		PrAboveMid	**Julian Day**
Subyearling Chinook	2012	***0.00***	***0.00***
	2011	***0.04***	***0.00***
	2010	***0.00***	***0.00***
	2009	***0.00***	0.94
	2008	***0.01***	***0.00***
Sockeye	2012	***0.00***	0.13
	2010	0.07	0.14
Steelhead	2011	0.67	0.89
	2009	0.73	0.99
	2008	0.44	0.95
Yearling Chinook	2012	***0.00***	0.06
	2011	***0.00***	0.77
	2010	***0.00***	***0.01***
	2009	***0.00***	***0.04***
	2008	0.48	0.92
Coho	2012	0.12	0.14
	2011	***0.02***	***0.03***
	2010	0.14	0.71
	2009	0.19	0.46
	2008	0.12	0.25

Subyearling Chinook

Full results of all ANCOVA analyses are available in Appendix A (Tables A.1-A.5). Sample counts for subyearling Chinook were high enough to allow for ANCOVA analyses for all five years of operations data. ***PrAboveMid*** was found to have a significant effect on the daily sample mortalities of subyearling Chinook in all five years analyzed while ***Julian Day*** was found to be significant in only four (2008, 2010-2012) of the years analyzed (Table 1). For the highest level of ***PrAboveMid***, least squares estimates of sample mortality were as high as 4.6% in 2010 and 4.7% in 2012 (Figure 1). In general, average sample mortality increased as ***PrAboveMid*** increased (Figure 1). In fact, Tukey's tests revealed that, for four of the five years analyzed, the least squares means sample mortality at the highest level of ***PrAboveMid*** (>95%) was significantly higher than that at the lowest level of ***PrAboveMid*** (<5%) (Figure 1).

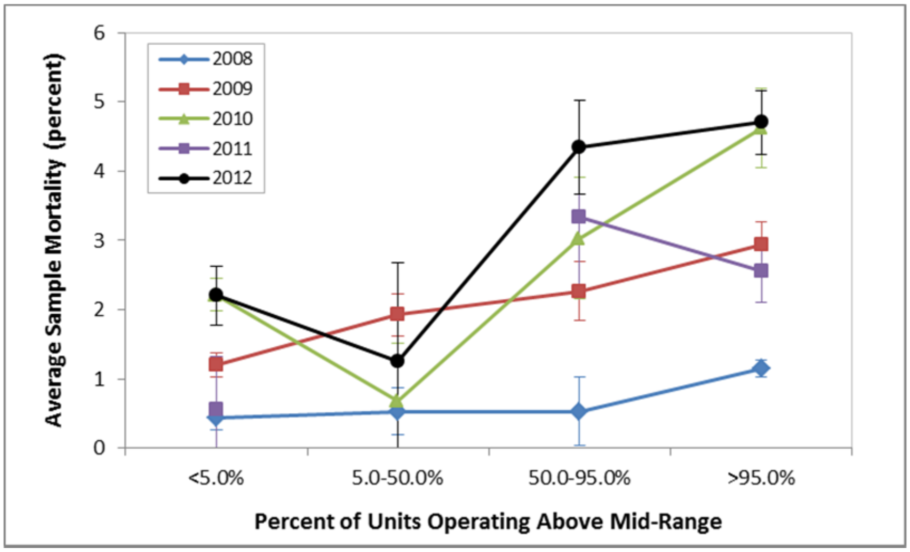

Figure 1. Least squares means sample mortalities (percent) (±SE) for subyearling Chinook in 2008-2012.

Sockeye

Sample counts for sockeye were only high enough to allow for ANCOVA analyses for two (2010 and 2012) of the five years. Among these two years, ***PrAboveMid*** was found to have a significant effect on the daily sample mortalities of sockeye in 2012 but not 2010 (Table 1). ***Julian Day*** was not significant in either year analyzed for sockeye (Table 1). For the highest level of ***PrAboveMid***, least squares estimates of sample mortality were as high as 8.9% in 2011 and 8.3% in 2012 (Figure 2). Although not always significant, average sample mortalities of sockeye tended to increase as ***PrAboveMid*** increased (Figure 2). As with subyearling Chinook, Tukey's tests revealed that, in 2012, the least squares means sample mortality at the highest level of ***PrAboveMid*** (>95%) was significantly higher than that at the lowest level of ***PrAboveMid*** (<5%) (Figure 2).

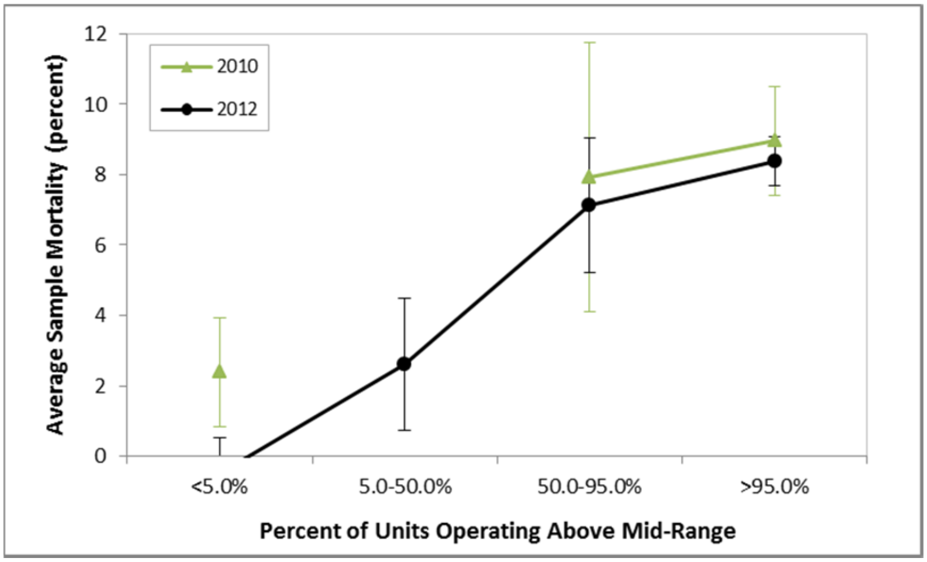

Figure 2. Least squares means sample mortalities (percent) (±SE) for sockeye in 2010 and 2012. Due to low sample counts, ANCOVA analyses for 2008, 2009, and 2011 were not possible.

Steelhead

Sample counts for steelhead were only high enough to allow for ANCOVA analyses for three (2008, 2009, and 2011) of the five years. In all three years, both ***PrAboveMid*** and ***Julian Day*** were found to not have a significant effect on the daily sample mortalities of steelhead (Table 1). Unlike for subyearling Chinook and sockeye, there was no discernible pattern in sample mortalities as ***PrAboveMid*** increased (Figure 3). In fact, Tukey's tests revealed no significant differences in the least squares means sample mortalities among the different levels of ***PrAboveMid*** (Figure 3). Finally, for all three years at all levels of ***PrAboveMid***, least squares means estimates of sample morality of steelhead were below 1% (Figure 3).

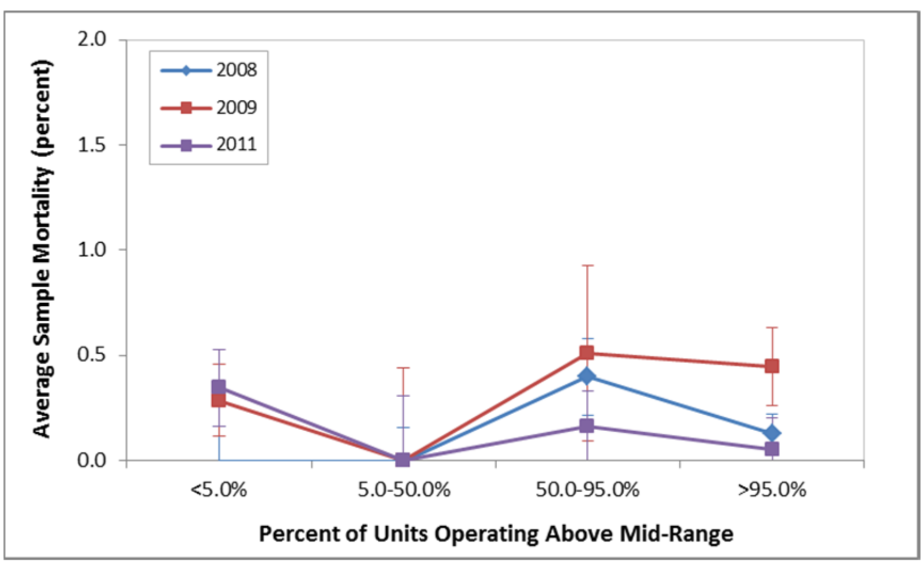

Figure 3. Least squares means sample mortalities (percent) (±SE) for steelhead in 2008, 2009, and 2011. Due to low sample counts, ANCOVA analyses for 2010 and 2012 were not possible.

Yearling Chinook

Sample counts for yearling Chinook were high enough to allow for ANCOVA analyses for all five years of operations data. ***PrAboveMid*** was found to have a significant effect on the daily sample mortalities of yearling Chinook in four (2009-2012) of the five years analyzed while ***Julian Day*** was found to be significant in only two (2009 and 2010) of the years analyzed (Table 1). The highest least squares means estimates of sample mortality tended to occur at the higher levels of ***PrAboveMid***, but all were below 2.5% (Figure 4). Among the years when ***PrAboveMid*** was a significant factor, average sample mortality tended to increase as ***PrAboveMid*** increased (Figure 4). This is particularly clear in 2009, 2010, and 2012. In fact, Tukey's tests revealed that, in these three years, the least squares means sample mortality at the highest level of ***PrAboveMid*** (>95%) was significantly higher than that at the lowest level of ***PrAboveMid*** (<5%) (Figure 4).

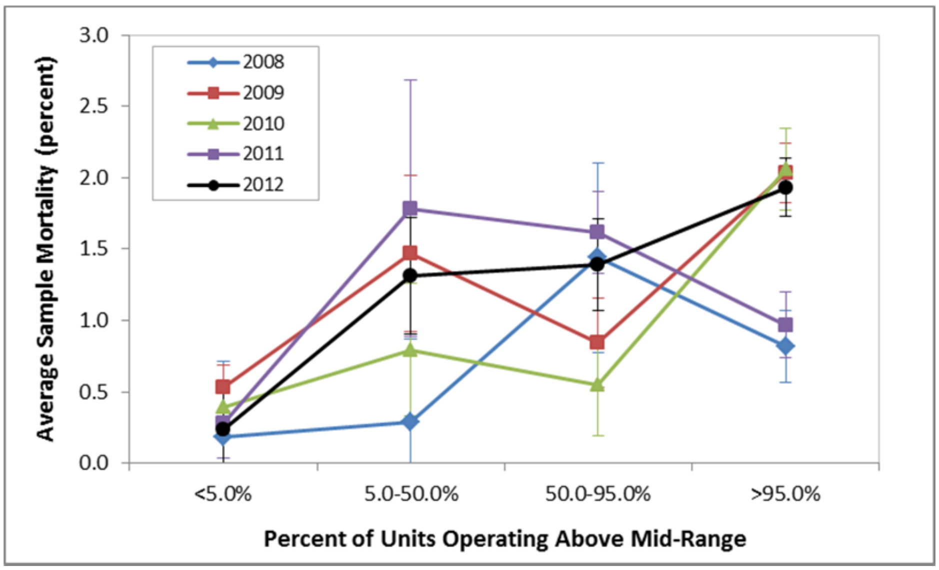

Figure 4. Least squares means sample mortalities (percent) (±SE) for yearling Chinook in 2008-2012.

Coho

Sample counts for coho were high enough to allow for ANCOVA analyses for all five years of operations data. ***PrAboveMid*** and ***Julian Day*** were found to have a significant effect on the daily sample mortalities of coho in only 2011 (Table 1). ANCOVA analyses for all other years revealed no significant effect of ***PrAboveMid*** or ***Julian Day*** on the daily sample mortalities of coho (Table 1). For all levels of PrAboveMid, least squares estimates of sample mortality for all five years were below 2.0% for coho. In addition, there was a great deal of variability in which levels of ***PrAboveMid*** resulted in the highest least squares means estimates of sample mortality. For example, in 2008, the highest average sample mortality occurred at the lowest level of ***PrAboveMid*** whereas in 2010, 2011, and 2012, the highest average sample mortality occurred when ***PrAboveMid*** was in the 50-95% range (Figure 5). Tukey's tests only revealed a significant difference in sample mortalities among the different levels of ***PrAboveMid*** in 2011. In 2011, when ***PrAboveMid*** was in the 50-95% range, the average sample mortality was significantly higher than that at the lowest level of ***PrAboveMid*** (<5%) (Figure 5).

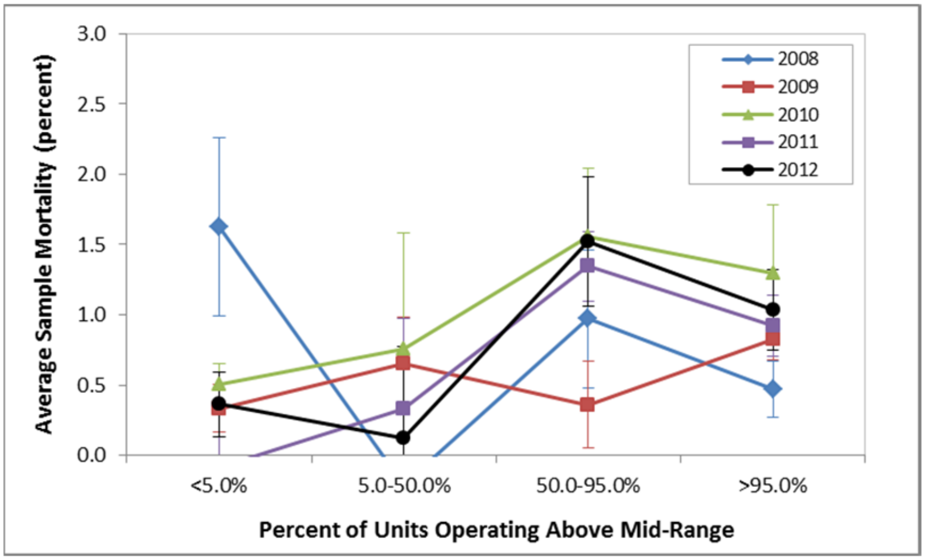

Figure 5. Least squares means sample mortalities (percent) (±SE) for coho in 2008-2012.

Discussion and Conclusion:

Among the five years and five species analyzed, ***Julian Day*** was determined to be a significant factor in sample mortalities for subyearling Chinook (2008, 2010-2012), yearling Chinook (2009 and 2010), and coho (2011) (Table 1). The variable ***Julian Day*** encompasses many factors, including changes in temperature over time, changes in fish length over time, and changes in operations over time. Because of this, it is difficult to determine what a significant effect of ***Julian Day*** signifies from a management perspective. For example, there are a series of releases of subyearling Chinook juveniles from Spring Creek National Fish Hatchery in April and early May of each year. These fish are typically small and, in the past, have been more affected by operations of BON-PH2. Because these Spring Creek fish are typically the only subyearling Chinook passing BON in April and early May, it may appear that sample mortalities are higher during this period than later in the season when subyearling Chinook from the Upper Columbia and Snake River are passing BON. In fact, of the four years where ***Julian Day*** was a significant factor, the coefficient estimate was negative in three years (2010-2012), which suggests that, as ***Julian Day*** increased, sample mortality for subyearling Chinook decreased. On the other hand, for the two years where ***Julian Day*** was a significant factor for yearling Chinook, the coefficient estimate was positive, which suggests that, as ***Julian Day*** increased, sample mortality also increased. As mentioned earlier, these inconsistencies in the "direction" of the effect of ***Julian Day*** make any attempt at management of this factor difficult.

Based on these ANCOVA analyses, there is evidence that operating the units at BON-PH2 above the mid-range of the 1% efficiency curve can result in increased sample mortalities, particularly for subyearling Chinook, sockeye, and yearling Chinook. In addition, there was consistency in the "direction" of this effect for these species. In general, as ***PrAboveMid*** increased, sample mortalities also increased (Figures 1, 2, and 4). This effect was particularly clear for subyearling Chinook and sockeye in 2012, where the average sample mortalities of these two species increased substantially as ***PrAboveMid*** increased (Figures 1 and 2).

APPENDIX A

Results from ANCOVA Analyses

Table A.1. Results from ANCOVA analysis of 2012 mortality data and effects of ***PrAboveMid*** and ***Julian Day***. CH0 = subyearling Chinook, SO = sockeye, CH1 = yearling Chinook, and CO = coho. Due to low sample counts, ANCOVA analysis of steelhead was not possible.

Species	Variable	D.F.	Type III S.S.	M.S.	F-Ratio	p-value
CH0	PrAboveMid	3	124.02	41.34	6.90	***0.00***
	Julian Day	1	190.69	190.69	31.82	***0.00***
	Error	75	449.46	5.99		
SO	PrAboveMid	3	144.68	48.23	13.82	***0.00***
	Julian Day	1	8.61	8.61	2.47	0.13
	Error	19	66.28	3.49		
CH1	PrAboveMid	3	28.71	9.57	8.32	***0.00***
	Julian Day	1	4.10	4.10	3.57	0.06
	Error	64	73.57	1.15		
CO	PrAboveMid	3	5.06	1.69	2.06	0.12
	Julian Day	1	1.87	1.87	2.29	0.14
	Error	33	27.03	0.82		

Table A.2. Results from ANCOVA analysis of 2011 mortality data and effects of ***PrAboveMid*** and ***Julian Day***. CH0 = subyearling Chinook, ST = steelhead, CH1 = yearling Chinook, and CO = coho. Due to low sample counts, ANCOVA analysis of sockeye was not possible.

Species	Variable	D.F.	Type III S.S.	M.S.	F-Ratio	p-value
CH0	PrAboveMid	2	100.23	50.11	3.31	***0.04***
	Julian Day	1	575.81	575.81	38.05	***0.00***
	Error	120	1,815.97	15.13		
ST	PrAboveMid	3	0.30	0.10	0.53	0.67
	Julian Day	1	0.00	0.00	0.02	0.89
	Error	21	4.02	0.19		
CH1	PrAboveMid	3	21.89	7.30	4.59	***0.00***
	Julian Day	1	0.13	0.13	0.08	0.77
	Error	73	116.10	1.59		
CO	PrAboveMid	3	9.21	3.07	3.67	***0.02***
	Julian Day	1	4.51	4.51	5.39	***0.03***
	Error	35	29.27	0.84		

Table A.3. Results from ANCOVA analysis of 2010 mortality data and effects of ***PrAboveMid*** and ***Julian Day***. CH0 = subyearling Chinook, SO = sockeye, CH1 = yearling Chinook, and CO = coho. Due to low sample counts, ANCOVA analysis of steelhead was not possible.

Species	Variable	D.F.	Type III S.S.	M.S.	F-Ratio	p-value
CH0	PrAboveMid	3	92.00	30.67	6.62	***0.00***
	Julian Day	1	280.12	280.12	60.45	***0.00***
	Error	111	514.38	4.63		
SO	PrAboveMid	2	71.65	35.83	3.08	0.07
	Julian Day	1	28.108	28.10	2.42	0.14
	Error	16	186.11	11.63		
CH1	PrAboveMid	3	22.13	7.37	9.85	***0.00***
	Julian Day	1	4.93	4.93	6.59	***0.01***
	Error	65	48.65	0.75		
CO	PrAboveMid	3	3.95	1.32	1.94	0.14
	Julian Day	1	0.10	0.10	0.14	0.71
	Error	33	22.41	0.68		

Table A.4. Results from ANCOVA analysis of 2009 mortality data and effects of ***PrAboveMid***, ***Units***, and ***Julian Day***. CH0 = subyearling Chinook, ST = steelhead, CH1 = yearling Chinook, and CO = coho. Due to low sample counts, ANCOVA analysis of sockeye was not possible.

Species	Variable	D.F.	Type III S.S.	M.S.	F-Ratio	p-value
CH0	PrAboveMid	3	49.93	16.64	8.06	***0.00***
	Julian Day	1	0.01	0.01	0.01	0.94
	Error	117	241.67	2.07		
ST	PrAboveMid	3	0.51	0.17	0.44	0.73
	Julian Day	1	0.00	0.00	0.00	0.99
	Error	33	12.90	0.39		
CH1	PrAboveMid	3	25.10	8.36	9.54	***0.00***
	Julian Day	1	3.72	3.72	4.24	***0.04***
	Error	70	61.40	0.88		
CO	PrAboveMid	3	2.14	0.71	1.65	0.19
	Julian Day	1	0.24	0.24	0.56	0.46
	Error	43	18.59	0.43		

Table A.5. Results from ANCOVA analysis of 2008 mortality data and effects of ***PrAboveMid***, ***Units***, and ***Julian Day***. CH0 = subyearling Chinook, ST = steelhead, CH1 = yearling Chinook, and CO = coho. Due to low sample counts, ANCOVA analysis of sockeye was not possible.

Species	Variable	D.F.	Type III S.S.	M.S.	F-Ratio	p-value
CH0	PrAboveMid	3	8.50	2.83	4.20	***0.01***
	Julian Day	1	11.62	11.62	17.22	***0.00***
	Error	70	47.22	0.67		
ST	PrAboveMid	3	0.25	0.08	0.95	0.44
	Julian Day	1	0.00	0.00	0.004	0.95
	Error	17	1.46	0.09		
CH1	PrAboveMid	3	3.31	1.10	0.83	0.48
	Julian Day	1	0.01	0.01	0.01	0.92
	Error	38	50.34	1.32		
CO	PrAboveMid	3	4.68	1.56	2.18	0.12
	Julian Day	1	0.98	0.98	1.38	0.25
	Error	23	16.42	0.71		

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DATA REQUEST FORM

Request Taken By: Brandon Chockley **Date:** 18-July-2012

Data Requested By:

Name: Tom Lorz (CRITFC) **Phone:**

Address: on behalf of FPOM **Fax:**

Email:

Data Requested:

Is there evidence that operating above mid-range of 1% efficiency curve at BON-PH2 has an effect on sample mortality.

Data Format: Hardcopy ☐ Text ☐ Excel ☐

Delivery: Mail ☐ Email ☐ Fax ☐ Phone ☐

Comments:

Analysis for FPOM Task Group - BON unit operating range

Data Compiled By: [signature] Jerry McCann **Date:** 17-Dec-2012

Request # 72

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